



LIMITS ON BIOLOGICAL UPLIFT OF STREAM RESTORATION FROM PROXIMITY OF SOURCE POPULATIONS

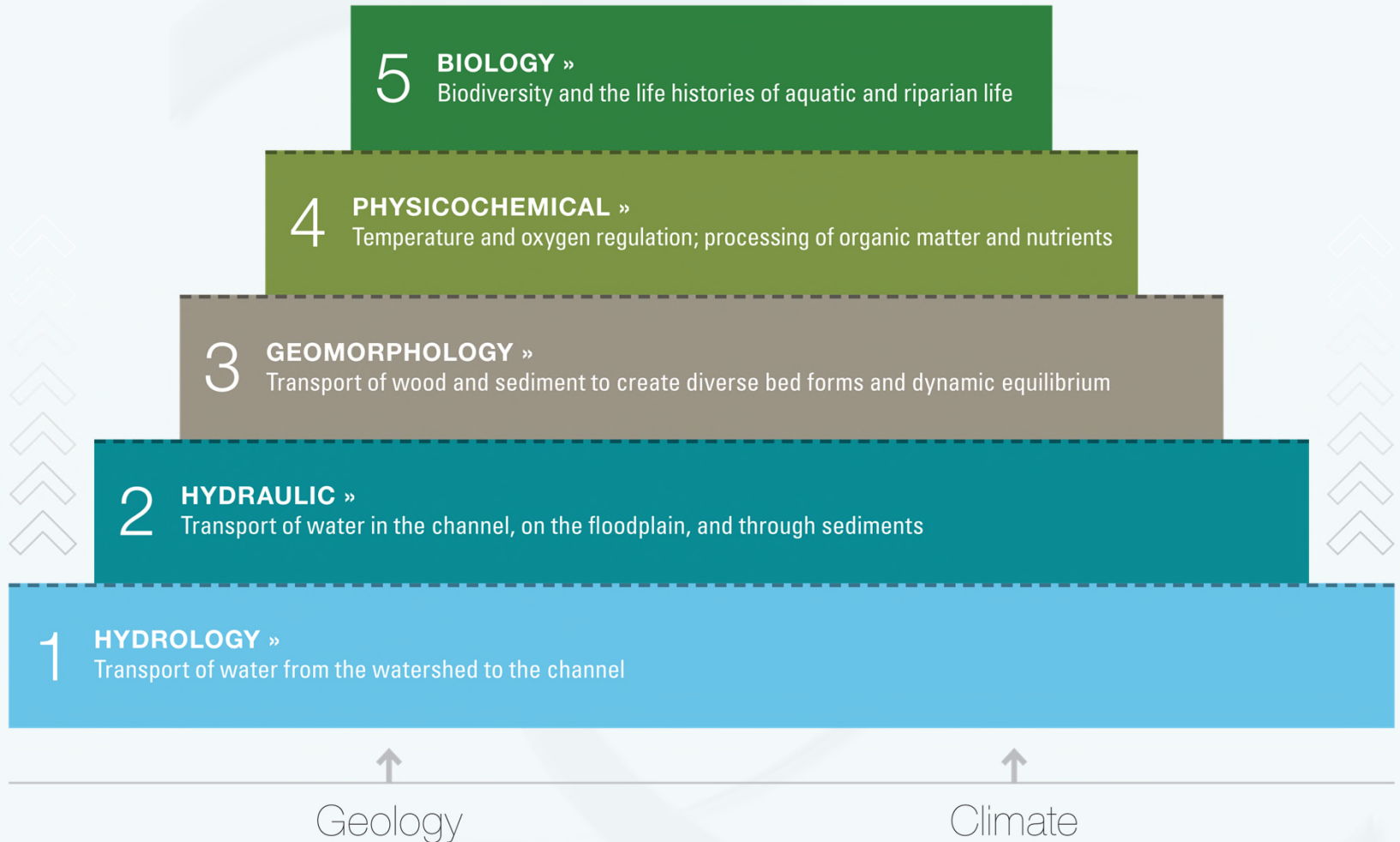
A photograph of a waterfall cascading over mossy rocks in a dense forest. The water is white and frothy as it falls, and the surrounding rocks are covered in green moss and fallen leaves.

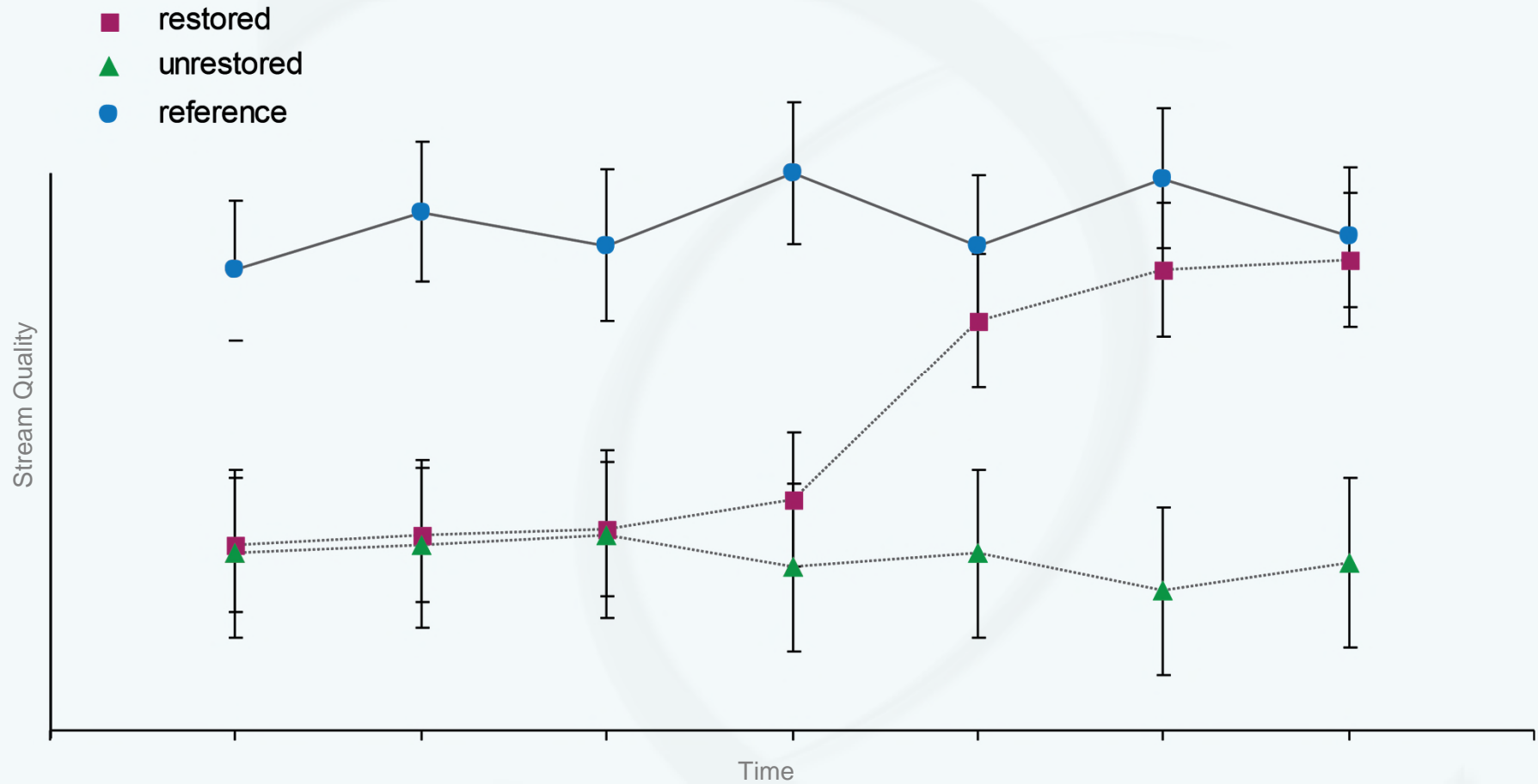
Mark Southerland
Chris Swan
Andrea Fortman

1. Quandary of Biological Uplift
2. Research Question
3. Methods and Analysis
4. Results and Conclusion
5. Use of Results

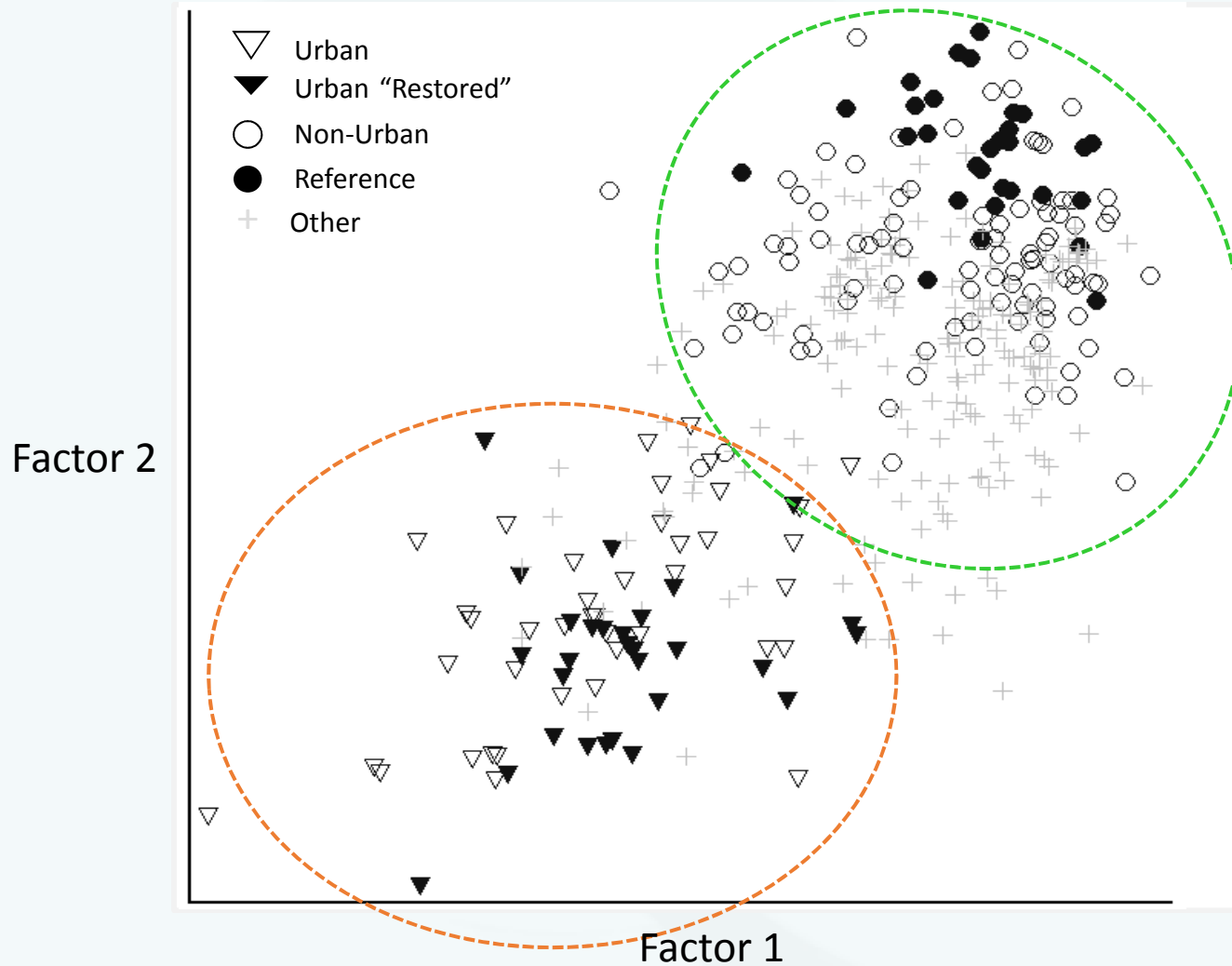


Stream Function Pyramid





Restoration Sites Do Not Match Reference Sites



General question:

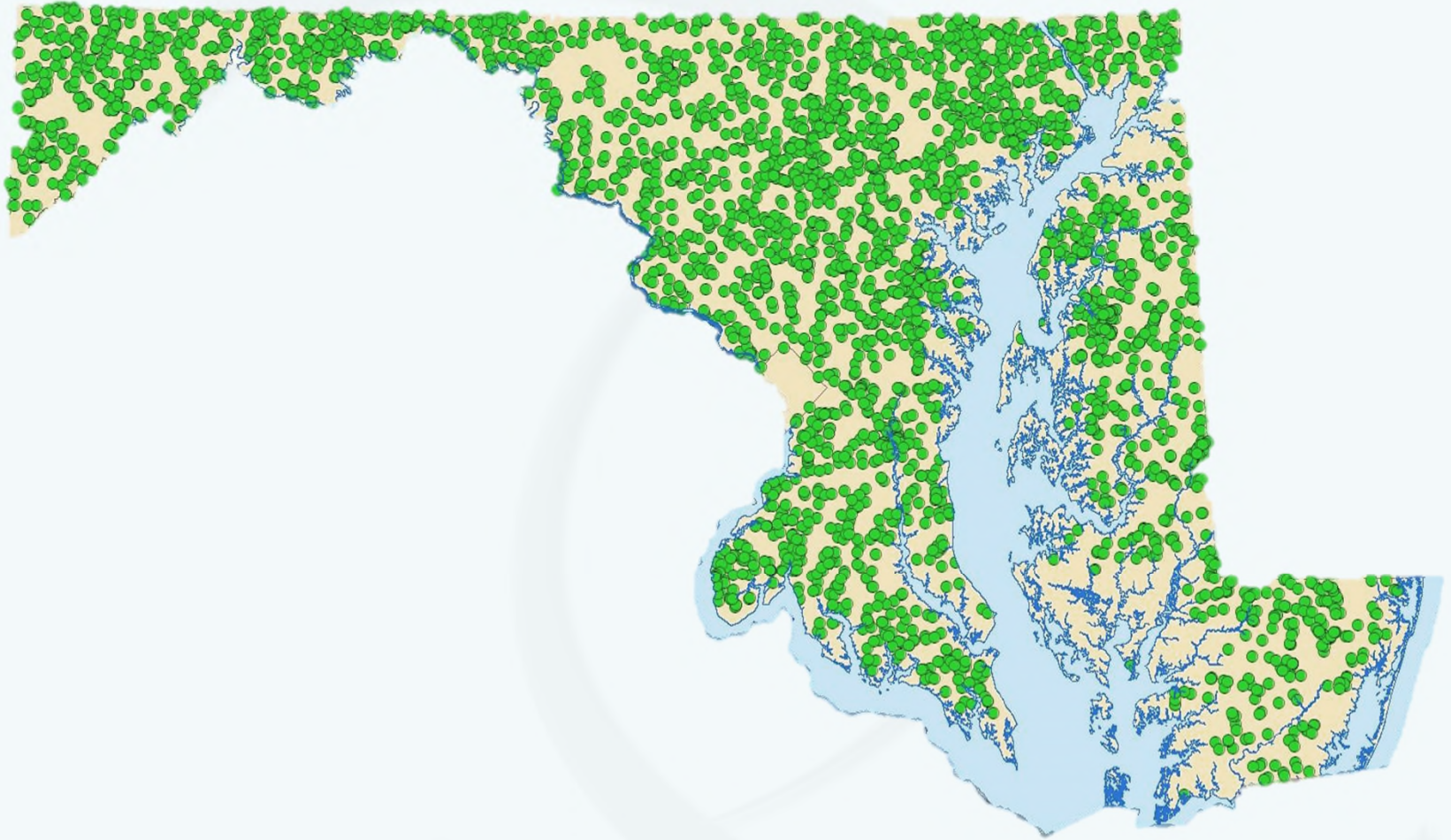
- What is the effect of site condition on the outcomes of stream restoration?

Specific question:

- What is the effect of the proximity of high-quality biological assemblages on the success of stream restoration in terms of biological uplift?

- Restoration site data
- Stream quality reference site data
- Statistical analysis
 - Range of values
 - Linear regression
 - Multiple regression

- MBSS or comparable Montgomery County sampling methods
- Benthic Index of Biotic Integrity (BIBI) converted to single 1-5 scale
- 625 reference sites with distance to restoration sites calculated along stream network
- Reference defined as BIBI of 2.75 (comparable to non-impaired)

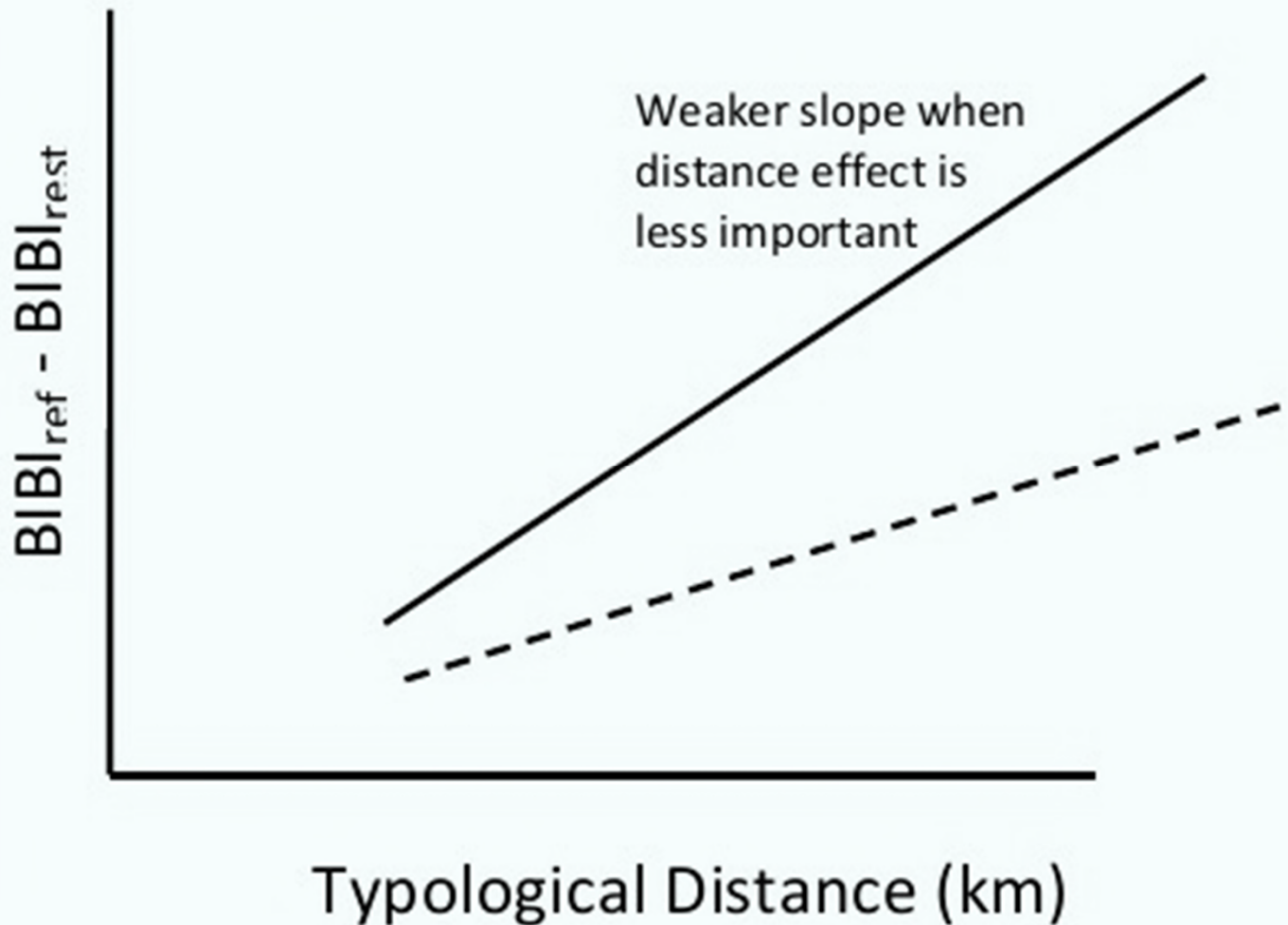


- 30 restoration sites with biological data
 - Anne Arundel
 - Baltimore County
 - Carroll County
 - Frederick County
 - Harford County
 - Howard County
 - Montgomery County
- 18 sites with post-construction data
- 12 sites with sampling ≥ 2 years post construction and ≥ 3 references sites

Thanks to all our partners



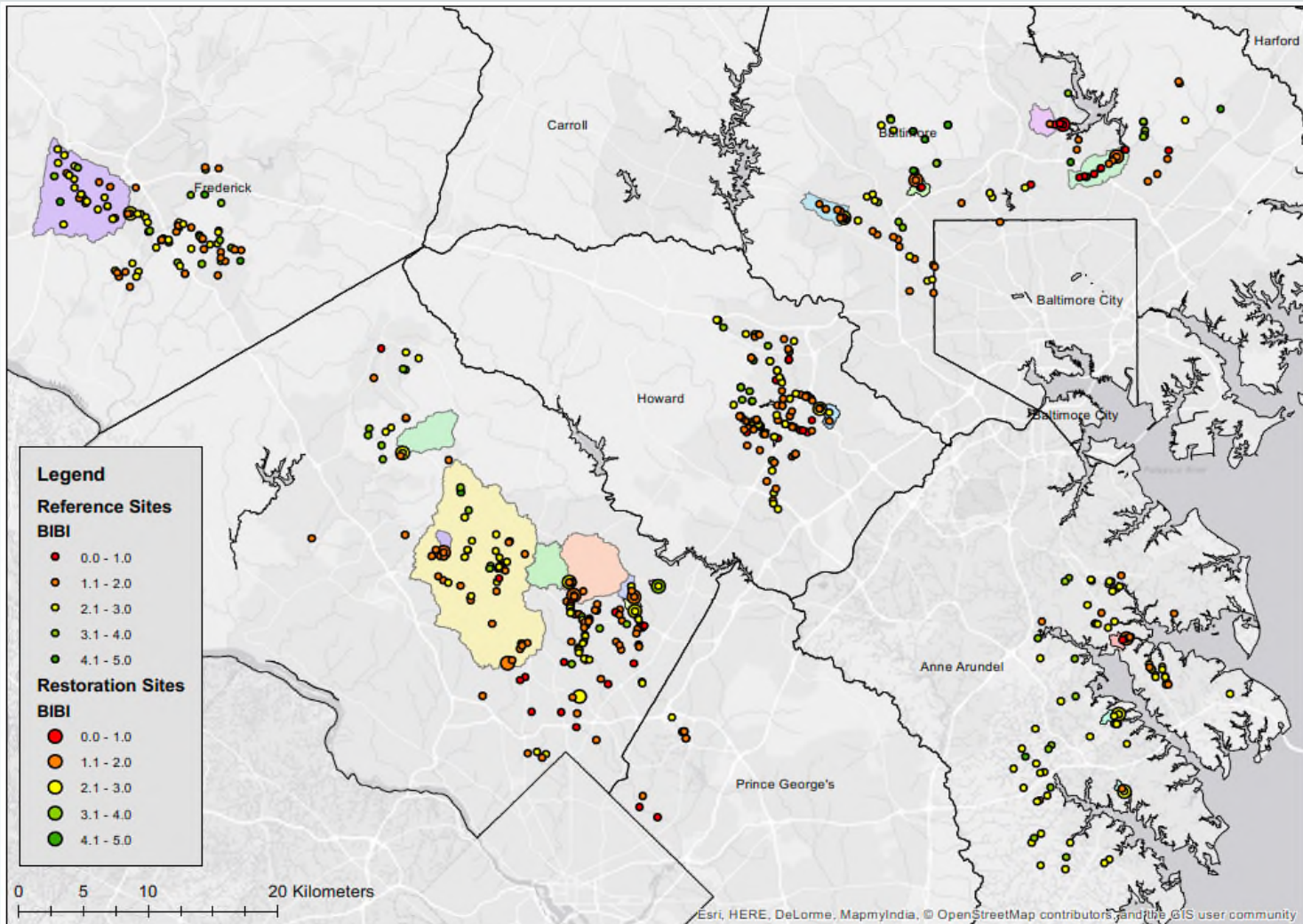
- Distance between reference and reference sites within a 15-km radius of the restoration site (Sunderman et al. 2011)
- Calculated shortest along-stream-network (typological) distance between the restoration site and each reference site
- Calculated the difference in BIBI scores ($BIBI_{ref} - BIBI_{rest}$)
- Regressed the degree of difference in BIBI scores against typological distance
- Multiple regression accounting for
 - Distance between reference and restoration sites
 - Times sampled at reference and restoration sites
 - Drainage area of reference site



Restoration Site Sampling

Site	Year Restored	Eco Region	County	DA (ac)	IA (%)	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Wilelinor	2006	Coastal Plain	Anne Arundel	151.40	30.04								2.14	1.57	1.86	3.00	1.86	2.14	2.14	2.71	2.14	
Howards Branch	2000	Coastal Plain	Anne Arundel	247.38	1.05								1.86	2.43	2.14	2.71	2.71	2.71	2.43	2.71	3.00	
Dividing	2015	Coastal Plain	Anne Arundel	257.70	18.46											2.71	2.14	2.43	2.14	1.86		
Cypress	2013	Coastal Plain	Anne Arundel	275.70	38.80										1.57	1.57	1.57	1.86	2.14		1.57	
Muddy Branch	2016	Coastal Plain	Anne Arundel	364.17	1.39															3.86	3.86	1.29
Woodvalley	2005	Piedmont	Baltimore	392.49	10.64											2.00	1.67	1.67				
Spring Branch	2008	Piedmont	Baltimore	1006.08	14.73											1.67	1.67	1.00	1.00			
Scott's Level	2014	Piedmont	Baltimore	1150.06	22.18												1.33	1.00	1.00		3.00	
Minebank Run	2014	Piedmont	Baltimore	2121.17	15.08											1.33	1.33	2.33	1.00	1.00		
Piney Run	2016	Piedmont	Carroll	9483.48	16.47															2.67	2.33	2.33
Little Tuscorora	2016	Piedmont	Fredrick	3575.69	4.72														3.00	3.00	3.00	3.00
Ballenger Creek	2007	Piedmont	Fredrick	9731.18	6.79				2.00	2.50	2.75	2.50	2.25	2.75	3.25	3.00	2.50	2.50		2.50		
Wheel Creek	2016	Piedmont	Harford	432.09	23.66							1.00				2.67	3.00	2.33	1.33	2.00	1.00	2.70
Red Hill Branch Lpax	2012	Piedmont	Howard	52.55	12.74											2.67	1.67	1.67	2.00	2.00	2.33	
Dorsey Hall Lpax	2015	Piedmont	Howard	3701.69	19.30															2.67	3.00	
Batchellors Run East	2013	Piedmont	Montgomery	568.46	3.15					4.00					3.00							
Breewood Tributary	2015	Piedmont	Montgomery	51.80	31.79											1.75	2.25	1.75	2.00	1.00		2.50
Bryants Nursery Run	2013	Piedmont	Montgomery	315.14	5.05					2.25					3.50							
Goshen Branch	2013	Piedmont	Montgomery	2494.13	1.29						2.67	2.67			2.67	3.00					2.33	
Gum Springs Trib	2013	Piedmont	Montgomery	232.47	8.10						1.67	2.67			2.00		2.67				2.33	
Hollywood Branch	2015	Piedmont	Montgomery	388.54	16.47											1.50		1.50				
Left Fork Paint Branch	2013	Piedmont	Montgomery	81.79	9.71								2.67			4.00					3.67	
Lower Donnybrook	2015	Piedmont	Montgomery	221.63	36.85												1.25	1.00	2.25			
Mill Creek and Tribs	2013	Piedmont	Montgomery	329.43	17.64						2.00	1.00				1.00	1.67				1.33	
Northwest Branch	2013	Piedmont	Montgomery	7104.02	5.19										2.33					2.00	2.67	
Northwest Branch - Batchellors Run I & II	2013	Piedmont	Montgomery	2136.67	3.82					2.50					2.25					2.00		
Sherwood Forest	2014	Piedmont	Montgomery	552.88	9.94					2.00					1.25							
Turkey Branch - Rock Creek NW Branch	2007	Piedmont	Montgomery	26129.05	14.64			1.50				1.50			1.00		2.00	1.25				
Upper Northwest Branch	2013	Piedmont	Montgomery	3310.82	6.51		3.25			1.75					3.00							
Upper Right Fork Paint Branch	2013	Piedmont	Montgomery	473.25	6.68						3.33	1.33			1.00	1.67					2.00	

Pre-restoration Restoration Year Post-restoration



- Catchment sizes (mostly < 5000 ac)
- Distance between restoration and reference sites (evenly distributed)
- Differences in years sampled (evenly distributed)
- Years that sampling occurred post-construction (max of 15 years), but only 12 sites ≥ 2 years

Two Analyses:

- Mixed-effects model regression of differences in BIBI scores ($\text{BIBI}_{\text{ref}} - \text{BIBI}_{\text{rest}}$) considering the effects of (1) site alone, (2) typological distance between restoration and reference sites, (3) differences in year of sampling between sites, (4) size of drainages to sites, and (5) all interaction terms
- Simple linear regressions of difference between reference streams ($\text{BIBI} \geq 2.75$) and the BIBI of the monitoring sites

Distance to Good Sites is Significant

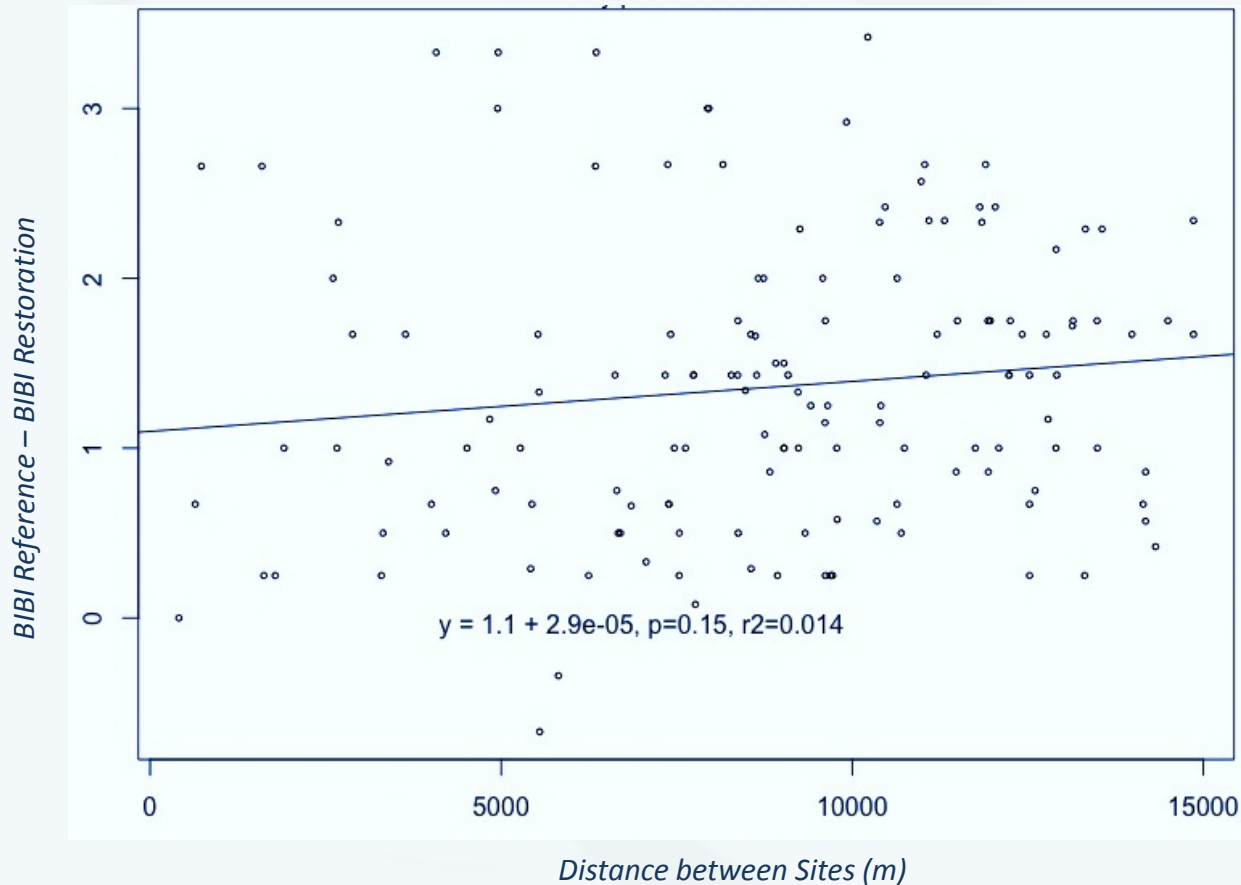
SOV	Estimate	Standard Error	t	P
(Intercept)	5.42E-01	1.64E-01	3.307	0.001231
Site-Cypress	8.61E-01	1.52E-01	5.673	9.11E-08
Site-Goshen Branch	3.49E-01	1.79E-01	1.946	0.053923
Site-Gum Springs Trib	1.02E-01	2.98E-01	0.341	0.733395
Site-Howards Branch	-4.32E-01	2.37E-01	-1.822	0.070759
Site-Left Fork Paint Branch	-1.21E+00	3.59E-01	-3.375	0.000983
Site-Mill Creek and Tribs	1.45E+00	1.77E-01	8.181	2.62E-13
Site-Northwest Branch	-9.16E-02	2.18E-01	-0.42	0.674883
Site-Red Hill Branch Lpax	4.72E-01	1.54E-01	3.068	0.002639
Site-Spring Branch	1.76E+00	2.03E-01	8.644	2.09E-14
Site-Turkey Branch-Rock Creek NW	1.06E+00	2.08E-01	5.086	1.29E-06
Site-Upper R Fork Paint Branch	4.69E-01	3.59E-01	1.306	0.19401
Site-Wilelinor	3.64E-01	1.80E-01	2.026	0.044836
Site-Woodvalley	1.89E+00	1.79E-01	10.543	< 2e-16
Distance	3.16E-05	1.38E-05	2.296	0.023345
Drainage	-6.35E-06	1.39E-05	-0.457	0.648374
Years	-5.25E-03	9.48E-03	-0.553	0.581087

Mixed-effects model regression of differences in B-IBI scores ($BIBI_{ref} - BIBI_{rest}$) against sites, typological distance between restoration and reference sites, differences in year of sampling between sites, and size of drainages to sites. Multiple $r^2 = 0.71$.

- Significant site effects
- Significant effect of distance to reference site at $p=0.023$
- Year difference with reference site, catchment size, and interactions were not significant, so were removed for parsimonious model (multiple $r^2=0.71$)

Site Relationships are Variable

Overall BIBI Difference Between Restoration & Monitoring Sites is Not Significant
>1 year post Restoration



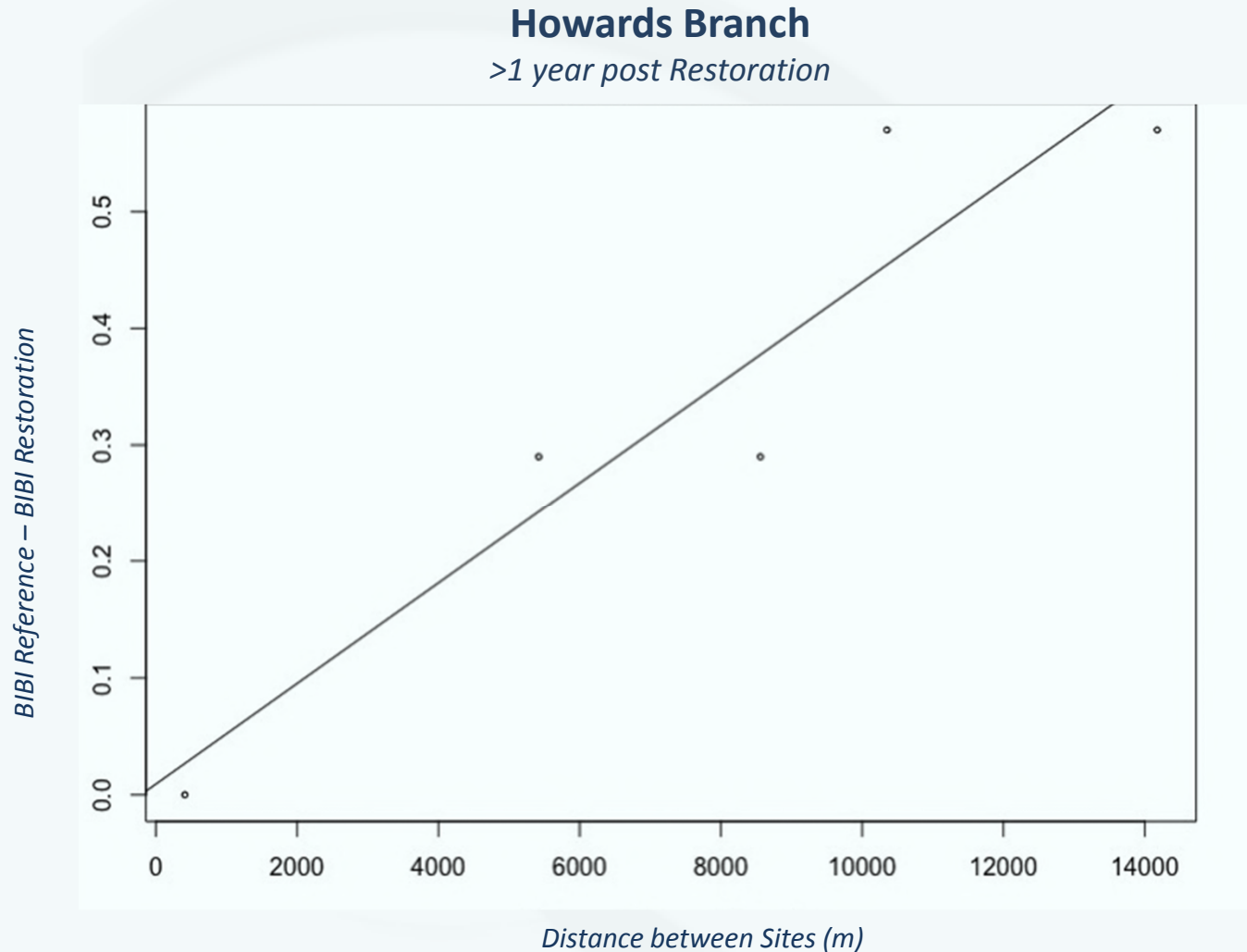
Only 4 of 12 Sites Show Uplift

Site	Intercept	Slope	p	r ²
Ballenger Creek	0.22	6.00E-05	0.012	0.17
Cypress	0.88	8.40E-05	0.09	0.2
Goshen Branch	1.1	-1.75E-06	0.96	0.0003
Gum Springs Trib	0.84	-1.10E-05	0.77	0.13
Howards Branch	0.009	4.30E-05	0.02	0.88
Mill Creek and Tribs	1.9	3.36E-05	0.59	0.03
Northwest Branch	0.94	-4.20E-05	0.71	0.04
Red Hill Branch	0.21	1.00E-04	0.01	0.38
Spring Branch	3.6	-1.10E-04	0.05	0.55
Turkey Branch	3.9	1.00E-04	0.43	0.12
Wilelinor	0.02	1.03E-04	0.26	0.15
Woodvalley	2.8	-5.40E-05	0.41	0.06

Significant Proximity Effect with More Years Sampled Post Construction

- 4 sites with significant effect of proximity of good streams were sampled 3, 5, 7, and 15 years post construction
- 8 sites with non-significant proximity effect were sampled 6, 5, 5, 2, 2, 2, 2, 2 years post construction
- In general, the longer the site was sampled post-construction, the more likely was a significant proximity result

Best Example of Biological Uplift



Close Good Sites Can Help Biological Uplift

- Farther reference sites were away from the restored sites, the higher the difference in BIBI scores
- Biological condition is better when good sites are nearby
- Potential for biological uplift from restoration is limited by proximity of source populations—i.e., “if you build it, they may not come”

- Temper expectations for biological uplift from stream restoration projects
- Consider guidelines for restoration that incorporate good streams as “stepping stones” to facilitate dispersal from more remote species pools to recolonize depleted catchments

